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PROGRESS REPORT ON THE STRENGTH OF STRUCTURAL TIMBER.

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United States Department of Agriculture,

BUREAU OF FORESTRY.—Circular No. 32.

GIFFORD PINCHOT, Forester.

U. S. DEPARTMENT OF AGRICULTURE,

BUREAU OF FORESTRY,

Washington, D. C., August 8, 1904.

SIR: I have the honor to transmit herewith a paper entitled "Progress Report on the Strength of Structural Timber," by Dr. W. Kendrick Hatt, Civil Engineer in the Bureau of Forestry, and to recommend its publication as Circular No. 32 of the Bureau of Forestry.

Very respectfully,

GIFFORD PINCHOT, *Forester.*

Hon. JAMES WILSON,
Secretary of Agriculture.

PROGRESS REPORT ON THE STRENGTH OF STRUCTURAL TIMBER.

The Bureau of Forestry has received many requests from lumber operators, engineers, and architects for the partial results of the timber tests now being carried on by the Bureau to determine the mechanical properties of the various commercial timbers of the United States. The present circular is issued in response to this demand, and contains, among other things, the results of cross-bending tests on about 250 large beams of structural timber. These results are being added to from day to day, and the figures given below will be modified in later publications in accordance with the results of further tests. The tests here presented are, however, sufficiently numerous to indicate the structural values of the various species specified in Table I, and to serve as a basis for a revision of opinion, particularly with regard to the strength of such species as loblolly pine and western hemlock.

A more formal publication will follow shortly in the form of a bulletin, in which a detailed account of the methods and machines used in obtaining these results will be given, the individual tests tabulated, and a thorough analysis of the results themselves presented. The data on hand will allow the formulation of certain relations between the knots and strength and between the rate of growth and strength, and will form the basis for an intelligent revision of the present rules for the inspection and grading of timber.

TIMBER TESTS OF THE BUREAU OF FORESTRY.

In arranging these tests the Bureau of Forestry has limited its present programme (1) to those species that promise to be on the market for an indefinite period, (2) to actual market products, and (3) to such purely scientific work as forms the basis for correct methods of test.

The present knowledge of the structural value of the timbers of the United States in the form of large sticks is astonishingly meager. What tests have been made have been incomplete and defective in many respects. After the programme of the Bureau of Forestry is carried out there will exist authoritative and complete information concerning the mechanical properties of the commercial timbers of the United States. One object of the tests is to aid in the framing of definite inspection rules for the various grades of structural timber.

Special problems, like the determination of the proper species and sizes for forest products, such as box lumber and cross-arms for poles, are undertaken in cooperation with corporations whenever the results fit in with the general interests of forestry. Such information not only results in economy of design, but also clears away misconceptions and promotes the removal from specifications of many clauses which prevent the use of timber of high structural merit.

The programme also includes tests to determine the effect of artificial seasoning, such as is used in the operations preliminary to the preserving processes, and the effect of the presence of the preservatives themselves.

A limited amount of work of a purely scientific nature is carried on, involving a critical examination of the methods used in the general programme, and assuring that the programme will be guided to its most useful end.

The timber tests of the Bureau of Forestry have been made at the following timber-testing stations, in cooperation with the laboratories of the respective institutions whose equipment is made available for this work: University of California, Berkeley, Cal., L. E. Hunt in charge; Purdue University, Lafayette, Ind., W. K. Hatt in charge, H. D. Hartley, assistant; Division of Tests, Bureau of Chemistry, Washington, D. C., H. S. Betts in charge; Yale Forest School, New Haven, Conn., J. W. Toumey in charge, H. D. Tiemann, assistant.

The programme of the work, as planned at the present time, is as follows:

Tests to determine properties of structural timber:

Series I. Tests of the mechanical and physical properties of timber in forms found on the market. The material will be of actual sizes and grades of commercial products. The purpose is to determine moduli for design; to determine the value of woods now considered inferior; to determine the liability to knots, and the reducing factors due to these; to arrange a table of standard weights, and rules of inspection and grading; and partly to compare the properties of species from different regions.

Tests to determine the effect of variations in the conditions:

Series II. Effect of rate of application of load, including impact tests.

Series III. Effect of moisture.

Studies of the effect of technological processes:

Series IV. Preservatives.

Series V. Methods of seasoning.

Series VI. Fire retardants.

In Series I, for instance, the structural value of the loblolly pine and of the Pacific Coast timbers will be fully determined. These species are tested in the form of large sticks, such as bridge stringers, in which knots, crooked grain, and other defects that occur in structural sticks are present. The origin of the sticks and their condition of seasoning are carefully described. Photographs of the stick are taken and drawings made, locating all the knots and showing the amount of heart, sap, wane, etc. The sticks are graded by an experienced lumber inspector. The analysis of the tests of a large number of sticks will serve to determine relations between strength and kind and number of knots, and between strength and rate of growth.

In an investigation of a wood like red gum (*Liquidambar styraciflua*) the tests include not only building material, such as floor joists, but also an examination of the merits of the wood in the form of small clear stock, such as is used for carriage construction, implements, etc. The ability of the wood to withstand the operations of steaming and bending is also investigated. In the case of this timber, the tests have been made on specimens taken directly from the forest.

It is the intention to test structural timber generally in the green state. Certain sticks will be set aside, for the length of time necessary for a thorough drying, in order to develop the defects arising during seasoning. The question of the distribution of moisture in the large sticks and the relative strength of green lumber and lumber that has been only partially dried on the surface will be taken up. It is apparent that lumber dealers do not keep large sticks on hand long enough to allow them to dry out thoroughly, and it does not seem at the present time that the surface dryness increases the strength of these large sticks in any marked degree.

SPECIES UNDER INVESTIGATION.

The species under investigation at the present time are: The Pacific Coast red fir (*Pseudotsuga taxifolia*), otherwise called Oregon pine or Douglas spruce; the western hemlock (*Tsuga heterophylla*); the red gum (*Liquidambar styraciflua*); the longleaf pine (*Pinus palustris*); and the loblolly pine (*Pinus taeda*). Later on, the redwood (*Sequoia sempervirens*) and western yellow pine (*Pinus ponderosa*) will be tested.

DESCRIPTION OF TESTS.

TESTS OF LOBLOLLY PINE.

Loblolly pine has not only a wide range of distribution but also a wide range of structural merit.

It is found locally on the markets of Washington, D. C., and Norfolk, Va., under the name of Virginia pine, in small sticks 8 by 8 inches or 10 by 10 inches in cross section, showing almost entirely sapwood of so rapid a rate of growth that sometimes only 4 rings occur in 3 inches. This is second-growth timber, grown since the civil war, and usually very knotty. The same species occurs on the Charleston market, whence it is shipped to Philadelphia and the North under the name of North Carolina pine. In this case it is forest-grown lumber of large size, fairly free from knots, and of a high order of structural merit.

The loblolly pine as a tree is prolific, grows vigorously, and successfully holds its place in competition with other species in the forest. The operations of conservative forest management, such as are undertaken by lumber companies that look upon their forest holdings as part of their capital and reap periodic harvests of timber from them, concern themselves in the Southern States notably with loblolly pine. It is, therefore, a timber that engineers and architects may expect to find on the market for an indefinite period. The chief objection to loblolly pine is that, being usually sapwood, it decays rapidly when exposed. It is, however, a timber that may be treated with preservatives very successfully, on account of its open grain. For such treatment many of the inferior timbers can be used more successfully than the more solid timbers like longleaf pine.

Tables I, IIa, IIb, IIc, and III give the results of tests on loblolly pine obtained on the market of Washington and from a mill at Charleston, S. C.

The 8 by 8 inch green Virginia pine entered in the tables was cut about March, 1903, and tested about one month after cutting. This timber was "sap-stained." It has been shown that this staining, or "bluing," does not injure the strength of the wood. The modulus of rupture of these beams was 3,281 pounds per square inch, the modulus of elasticity 729,000 pounds per square inch, and the dry weight per cubic foot 26.3 pounds.

The 8 by 8 inch and 4 by 8 inch air-dried Virginia pine were cut in Stafford County, Va., and had been drying in the yard for two years and one year, respectively. The 8 by 8 inch showed a modulus of rupture of 4,874 pounds per square inch, a modulus of elasticity of 1,164,000 pounds per square inch, and a dry weight per cubic foot of 28.8 pounds. The 4 by 8 was timber of denser structure and of slower growth than the 8 by 8 inch. The air-dried pieces show a modulus of rupture of 6,319 pounds per square inch, a modulus of elasticity of 1,219,000 pounds per square inch, and a dry weight per cubic foot of 29.4 pounds.

Part of the 4 by 8 inch stuff was soaked to bring it to the green state, in order to obtain the relations between air-dry and green timber. The moisture was increased from 19.4 per cent to 46.3 per cent. The modulus of rupture of the soaked timber was decreased about 20 per cent, and the modulus of elasticity about 2 per cent.

This Virginia pine is usually second-growth timber, showing all sapwood on faces, very knotty, and wide ringed. It is not a timber for important engineering structures, but is used in the minor work of architects.

The 8 by 14 inch North Carolina pine was cut from the holdings of a lumber company near Charleston, S. C., about September 1, 1903, sawed September 15 to 18, 1903, and tested from two to five months after sawing. It is an average air-dry timber showing sapwood on all four faces, of "square edge" grade according to the standard inspection rules of 1902 of the Georgia Sawmill Association. The timber represents good structural timber, such as is used in warehouses, mills, and other structures where the conditions do not demand longleaf pine. The modulus of rupture was 6,187 pounds per square inch, the modulus of elasticity 1,479,000 pounds per square inch, and the dry weight per cubic foot 31.2 pounds. The distribution of moisture at the center of these 8 by 14 inch North Carolina sticks was determined by sawing out a section 1 inch thick halfway between the ends, dividing it into nine parts by cutting lengthwise and crosswise at the quarter points, and determining the moisture in the several parts. The average of the results on the ten sections from as many sticks is shown in Diagram I. The figures in the various parts of the section show the percentage of moisture in each part.

14 inches		
32.6 per cent.	31.9 per cent.	29.3 per cent.
30.7 per cent.	30.6 per cent.	33.2 per cent.
28.6 per cent.	30.9 per cent.	29 per cent.

Average 31.7 per cent.

DIAGRAM I.—Distribution of moisture in cross section midway of the length of North Carolina loblolly pine sticks. (Average of ten sections taken from sticks 8 by 14 inches by 16 feet.)

TESTS OF LONGLEAF PINE.

Longleaf pine has been for a long time the standard timber of construction, not only on account of its strength, hardness, and durability, but also on account of the long lengths of heartwood that can be obtained free from knots. At present the difficulty in obtaining long timbers of this wood has led manufacturers, notably in the case of car sills, to consider the efficiency of splices or to use the Pacific Coast

woods. Longleaf pine timber has been tested very largely, not only in the form of small sticks, but more rarely in large sticks as well.

In the markets at present any hard pine, whether longleaf, shortleaf, or loblolly, which shows a close-ringed, hard texture, goes under the name of longleaf pine. The names Georgia pine and Alabama pine are often used to designate timber coming from virgin tracts of longleaf pine in those States.

The tests quoted represent longleaf pine sticks of an excellent merchantable quality, the better part of them being nearly clear stock. Some of the sticks from Georgia were obtained in the New Haven market, having been shipped there from southern Georgia, and having been in the New Haven market for from three to six months. The remainder were obtained in yards at Washington, D. C., whither the sticks were shipped from Clinch County, Ga., about one year before testing. The longleaf pine from South Carolina was also excellent material. It is very noticeable in the tests that longleaf pine tends to check upon drying out and to fail by longitudinal shear. This is one reason for the belief that an engineer is not justified in using unit stresses larger than those obtained by tests upon green timber. The modulus of rupture of the Georgia longleaf was 8,384 pounds per square inch, the modulus of elasticity 1,820,000 pounds per square inch, and the dry weight per cubic foot 42.9 pounds.

In the case of both longleaf and loblolly pine, small sticks were sawed from the uninjured portion of the large sticks after testing. Further tests were made on these small sticks to determine the relation between the strength of the large and the small sticks, the relative strength of pieces of various rates of growth, and the effect of moisture when the variations due to knots and defects were eliminated. These minor tests were also made on sticks cut from red fir and western hemlock, as noted below.

Table III shows a comparison of these tests on the smaller sticks sawed from the larger sticks with the tests on the large sticks. It appears from this table that the modulus of rupture of the small clear sticks 2 by 2 inches in cross section is on an average about 30 per cent higher than that of the sticks from which they were cut. This increase varies from 100 per cent to 2 per cent. The modulus of elasticity, however, of small beams is only 92 per cent of that of the large beams. These values are based on a comparison of the average results of tests of sticks of various grades. Of course, the small clear sticks are relatively stronger than the parent sticks when the latter are of second grade—that is, contain large knots. Further facts may be determined from an inspection of Table III. It is reserved for a future bulletin to formulate rules governing the strength as affected by knots, crooked grain, rate of growth, and moisture.

The red fir of the Pacific Coast is known commercially under various names. In California and Oregon it is usually designated as Oregon pine; in the region of Puget Sound as yellow fir, Douglas spruce, and Puget Sound pine; while in northern Oregon and southern Washington, along the Columbia River, and in the eastern markets the name red fir is gradually becoming established and universal.

Botanically, the timber is derived from a single species, *Pseudotsuga taxifolia*. The range of its growth extends from Lower California to central British Columbia, and from the Pacific Ocean to the Rocky Mountains. It reaches its best development in western Washington and Oregon, between the summit of the Cascade Mountains and the Pacific. Almost pure forests are found here, which frequently yield from fifty to one hundred thousand board feet per acre. In these regions the tree will average 5 or 6 feet in diameter at the butt, with a height up to 300 feet.

The trunk of the tree is straight, and readily clears itself of branches. It is possible, therefore, to obtain exceptionally large and long pieces for structural purposes. Sticks 24 inches square and up to 100 feet long are regularly listed and obtainable in the merchantable grades. The possibility of procuring long and large pieces, combined with the exceptional strength and stiffness of the material compared with its weight, renders the red fir an ideal structural timber. Being almost entirely heartwood, the red fir is durable on exposure to the weather.

In the green logs from mature trees the sapwood is distinguished as a narrow light-colored ring, extending, usually, not more than 2 inches beneath the bark. In the seasoned timber one seldom encounters sapwood that is distinguishable; and although the adopted grading rules allow, for the merchantable grades, sapwood only on the corners, lumbermen have no difficulty in meeting the requirements.

Small trees varying from 1 to 3 feet in diameter are unsurpassed for spars, owing to the straightness of the trunk, the small angle of taper, and the length obtainable. Lengths from 50 to 110 feet are found on the market, while even longer ones are easily obtainable. Red fir is used on the Pacific Coast to the exclusion of other species for piling for docks and foundations for heavy structures in soft ground. The standard dimensions for this purpose are 12 inches in diameter and from 60 to 70 feet long.

The wood of the red fir varies in color from a light yellow to a pronounced red; and in grain from one so coarse that there are sometimes not more than 4 or 5 rings per inch in small trees or in heartwood to a fine, even grain with upward of 40 rings per inch. The rings are usually strongly marked, the summer wood being very dense and dark in color, while the springwood is much softer; and the wide-ringed wood is somewhat spongy. Owing to this marked difference in the

texture of the alternate rings and to the long, regular fiber, the wood splits easily, especially when dry, rendering it unfit for box shooks. This same characteristic makes it particularly pleasing for inside finish, paneling, etc., when slash-sawed. The porous springwood readily absorbs wood stains, while the dense summer rings are little affected, giving a beautiful finish in every shade desired.

Since it is comparatively free from resin and pitch pockets, the wood is adapted to dry-kiln seasoning. It is cut into every form of lumber, from rough structural timbers, used in the framing of heavy constructions of all kinds where strength and durability are required, to the fine-grained, clear stock of flooring.

The mechanical tests, a summary of the results of which is given in Tables I to III hereafter, were made upon market products. The sticks were graded by an experienced lumber inspector according to the Pacific Coast standard of 1900. As has been the experience in the timber tests of the Bureau of Forestry with other timbers, the grading of the inspector was found to correspond closely to the average results of the mechanical tests. The sizes given in Table I are those usually used in railroad work, in bridge and trestle construction, and in car construction.

Reference to the origin of the three shipments in Table I is omitted until the results of the tests are complete. Shipment B was of poorer quality than A and C.

It is evident from Table I that red fir is of varied quality, and that specifications need to be drawn somewhat more carefully than in the case of longleaf pine to exclude the wider-ringed quick growth and knotty sticks. Taking the 6 by 8 inch and 8 by 16 inch sticks of shipment C as representing an average quality of red fir, and including select, merchantable, and seconds, it appears that the modulus of rupture is 7,790 pounds per square inch, the modulus of elasticity 1,783,000 pounds per square inch, and the dry weight per cubic foot 28.5 pounds. The average rate of growth was nearly 19 rings per inch; that is to say, the tree added 1 inch to its radius, or 2 inches to its diameter, in 19 years.

It does not appear from the results of the tests that there is any marked difference in the strength of fir of red and yellow color, provided the sticks have the same rate of growth and are equally free from defects.

A series of tests on small clear sticks of straight grain indicates that a rate of growth corresponding to 21 rings per inch yields the greatest density and strength.

These red fir sticks were tested from six months to one year from the time of sawing. They were kept in a shed and sprinkled to prevent drying out. The exterior parts of the beams contained less moisture than the center, but the difference was not marked. An

examination of the distribution of the moisture throughout the cross section of the six 8 by 16 inch beams showed relations which are exhibited in Diagram II. A 1-inch cross section taken midway of the stick was divided into 9 parts at third points, as shown, and the moisture in the several parts of the sections determined. The figures recorded in the diagram are the average percentages of moisture found in each part.

16 inches.		
22.7 per cent.	24.2 per cent.	22.6 per cent.
25.1 per cent.	27.2 per cent.	24.5 per cent.
22.3 per cent.	24.8 per cent.	22.4 per cent.

Average 23.9 per cent.

DIAGRAM II.—Distribution of moisture in cross section midway of the length of red fir sticks.
(Average of six sections taken from sticks 8 by 16 inches by 16 feet.)

TESTS OF WESTERN HEMLOCK.

The introduction of western hemlock to the market as a building material has met with many obstacles. Without doubt the one offering the greatest opposition to the introduction has been the strong prejudice aroused by the name of hemlock, which is merited only by the Eastern species. So great is this prejudice even now that, although large quantities of the timber are cut and sold, it is sold under false or fictitious names, such as Alaska pine and Washington pine, spruce, or fir. Western hemlock, as such, has no market standing.

Western hemlock reaches its best development in Washington, in the region lying between the summit of the Cascade Mountains and the coast, but is also found from Alaska to central California and as far east as Idaho and Montana. The tree, where conditions have best favored its growth and development, will average 4 feet in diameter at the butt and 200 feet in height. The trunk is straight and cylindrical, but does not readily clear itself of branches. This causes the defect of small knots in the timber and makes it impossible to obtain much clear lumber except from large trees. The small proportion of clear sticks of hemlock in Table I is noticeable.

The wood of the mature tree is hard, straight and even grained, and nearly white in color. The sour odor of the lumber is unmistakable. There is not the marked difference in either color or hardness between the spring and summer rings that is noticeable in red fir. The wood does not split readily, and is light and tough. These qualities make it especially suitable for box manufacture. Knots are rather frequent, often dark brown to almost black in color, but usually tight and sound. The regular and even structure of the wood and the total absence of pitch render it capable of rapid kiln drying at high temperature without injury.

For flooring, molding, paneling, and all inside finish western hemlock makes a superior lumber, not easily scratched, susceptible of a high polish, and of excellent wearing qualities.

The results of the mechanical tests, although the data are not as yet sufficiently numerous for positive conclusions, indicate a quality of timber averaging about 70 per cent of the strength of red fir of the same grade, and suitable for all except the heaviest structures.

The tests of western hemlock recorded below were made upon timbers cut on the west slope of the Cascade Mountains, in Lane County, Oreg., and tested from two to six months after sawing. The sticks were stored in a shed and sprinkled from time to time. It is difficult to apply to the western hemlock the grading rules adopted for red fir. Their application throws most of the hemlock sticks into the "seconds" grade. New rules should be made for western hemlock to bring the better quality of sticks into the "merchantable" grade. The average of the results shown in Table I gives a modulus of rupture of 5,530 pounds per square inch, a modulus of elasticity of 1,261,000 pounds per square inch, and a dry weight per cubic foot of 26.8 pounds. The rate of growth of these sticks was 10.2 rings per inch.

RESULTS OF TESTS IN GENERAL.

SUMMARY OF TABLE I.

A digest of the results in Table I may conveniently be shown in the following table, which presents the strength and stiffness of beams such as are found in the market and are used by engineers. More detailed information will be found in Table I. The modulus of rupture is a factor which represents fairly well the strength of the timber. The modulus of elasticity is a factor which represents its stiffness.

Summary of Table I, showing cross-bending strength of structural timber.

Species.	Grade.	Average number of sticks.	Time seasoned.	Moisture.	Weight per cubic foot.		Modulus of rupture.	Modulus of elasticity.
					As tested.	Dry.		
Red fir:			Months.	Per cent.	Pounds.	Pounds.	Pounds per square inch.	1,000 lbs. per square inch.
Shipments A and C.	Select.....	22	6 to 12	22.6	37.1	30.2	8,810	1,925
	Merchantable.....	29		20.8	34.5	28.4	7,730	1,825
	Seconds.....	16		19.5	31.9	26.7	6,290	1,630
Shipment B....	Select.....	14	3	27.6	30.9	24.2	6,250	1,280
	Merchantable.....	15		26.5	33.7	26.6	5,340	1,320
	Seconds.....	25		26.2	35.1	27.8	4,280	1,400
Shipments A, B, and C.	Select.....	36		24.5	34.7	27.9	7,780	1,675
	Merchantable.....	44		22.7	34.8	28.4	6,920	1,650
	Seconds.....	41		23.6	33.8	27.4	5,070	1,490
Average of shipments A, B, and C.	All grades.....	121		23.6	33.4	27.8	6,580	1,570
Western hemlock....	do.....	30	3 to 6	32.2	35.4	26.8	5,565	1,260
North Carolina loblolly pine.	Square edge	20	3	37.2	42.8	31.2	6,187	1,479
Longleaf pine	Merchantable.....	26	6 to 12	26.7	53.3	42.1	8,210	1,790

This table is not considered to be a final statement of the relative structural value of the various species tested. The great range of values found in tests of timber render it necessary to perform tests on a large number of sticks. Furthermore, the moisture condition of the beams varies somewhat in the different species entered in Table I. The question of the effect of a longer time of drying in increasing or decreasing the strength of beams has not been satisfactorily investigated. Certain elements of the question may be noted. The moisture content is different in green timber of various species; for instance, about 50 per cent of the dry weight in the case of red fir, and up to 100 per cent in the case of loblolly pine; so that the same moisture content in these two species does not represent an equal degree of seasoning. Again, the red fir seasons more rapidly in the dry climate of California than does the loblolly pine in the moist climate of the Atlantic Coast. It is surprising how much moisture is found in well-seasoned timber. Attention is called to the fact that sticks of longleaf pine 10 by 12 inches in cross section which had been drying in the Washington yard for one year contained 35 per cent of moisture, and that sticks of loblolly pine from Virginia, 8 by 8 inches in cross section, that had been drying in the same situation for two years and were almost black on the surface, contained 34 per cent of moisture. The small sticks dry out more uniformly than do the large sticks, and after the moisture has been reduced to nearly 26 per cent the strength begins to increase upon a further reduction of moisture. The laws expressing the relation of strength and moisture in the case of small sticks, however, do not necessarily apply to large sticks. It is believed that the tests quoted in the above table were made on timber as delivered to the engineer under the ordinary conditions of the market.

A future bulletin will present the results on the individual sticks and give full information concerning the proportion of the results falling within a given range of strength. Photographs of the sticks will also be published.

STRENGTH AND COMPRESSION.

Table II a contains the results of tests in compression parallel to the fiber of various species of timber. These are on material derived from the beams listed in Table I. They are to be regarded as minor tests. The Bureau of Forestry has not yet installed a testing machine of sufficient capacity to allow tests on full-sized columns.

Table II b contains the results of tests in compression at right angles to the fiber. Loads were applied to a steel plate for 4 inches along the stick under test, and measurements were taken to determine the amount of yielding of the stick in the direction of the loading due to crushing of the surface or general compression of the stick. The elastic limit of the wood under this kind of loading is given in Table II b . The values represent the strength of wood against the bearing pressure of a washer.

When a beam becomes weakened by wind-shakes or season checks it is apt to fail under longitudinal shear. That is to say, it splits from the end of the beam toward the center, instead of failing in tension or compression at the center of the span. The liability to failure under longitudinal shear decides the strength of a beam of short span. Table II*d* indicates the strength of the various sticks in longitudinal shear. The strength is given in pounds per square inch of horizontal section of beam. The strength of the area of wood actually sheared off is greater than these values. The latter include the effect of openings in the wood between the fibers due to checks, etc. The values are those that should be used in designing beams to carry loads.

SHEARING STRENGTH.

The results of the tests to determine the actual shearing strength of the wood will be found in Table II*c*. These tests were made on small test pieces, a projecting bead on each of which was sheared off. The test piece was so designed as to yield a failure in true shear without an accompanying failure in compression or bending.

TESTS OF RED GUM.^a

Red gum is found in abundant quantities, principally in the river bottomlands of all the Mississippi Valley States south of the Ohio River and east of Texas, where the stumpage is estimated to be greater than the combined stumpage of all the other hardwoods, and along the swamps of the Atlantic Coast. Although at the present time a comparatively small amount is being cut, owing to the great care necessary in seasoning the wood, its future is most promising. As a forest tree the red gum is very tall and straight, varying, according to soil and climatic conditions, from 30 to 60 inches in diameter at the stump, and in height to the first limb from 40 to 80 feet. The percentage of waste, in comparison with other hardwoods, is very small, and for clear, wide lumber this is as valuable a tree as poplar or cottonwood. Red gum is now being used extensively for barrel staves, for which purpose it is rapidly replacing elm. Some tight barrels are being made from red gum, but, owing to the more favorable properties of the oaks for this purpose, its future use will probably be limited for some time to the slack barrel.

Another important use of red gum, where strength is an essential feature, is in the manufacture of tobacco and canners' boxes and for crating for heavy machinery. For boxes the wood has, within the last few years, been used along with sycamore, poplar, and cottonwood.

^a Also called sweet gum and star-leaved gum.

Owing to the value of the clear, wide lumber cut from the red gum log, it is too expensive a wood to use for construction timber while the supply of pine, fir, and hemlock is so great. However, the red gum has local uses for building material, such as joists, sills, and common frames. The material is usually cut from the heart of the tree, which, on account of shakes, etc., is not used for other purposes. Results of tests on a few of these joists are shown in Table IV. The supply of red gum timber for this use is so limited that it is hardly available for general engineering construction.

The tests of red gum, quoted in Table V, are on 4 by 4 inch sticks sawed from trees selected from the forest by agents of the Bureau of Forestry in the Tennessee River bottoms at Hollywood, Ala. Both mature and young trees are represented. These tests form part of a series which will eventually cover the Atlantic Coast and the Mississippi Valley ranges of the tree. It will be noticed that there was a considerable number of culls from the logs. Fifty-three per cent of the heart pieces sawed out were discarded.

The results of compression tests parallel to the grain on specimens of red gum cut from 10 trees at Risco, Mo., are added to Table V.

The tests include an examination of the relative strength of the wood at various parts of both young and mature trees from various localities, which will form a portion of a general bulletin on red gum to be issued in the near future by the Bureau of Forestry. In the tables given in this circular the strength of the red gum is given as ascertained from the general run of the trees from the Tennessee River bottoms at Hollywood, Ala. Five mature and 5 immature trees were cut. Three logs 16 feet long were taken from each trunk. Four by four inch test pieces were cut from a plank which was sawed from the trunk, to include the center of the heart of the tree. Part of the material is to be tested green, part kiln-dried, and part air-dried, in cross bending, compression parallel to the fiber, and compression at right angles to the fiber. An analysis of the results will attempt a determination of the relative strength of the fiber throughout the height of the tree, and of the relative strength from the heart center to the bark. While it is possible to ascertain these relations in the case of a tree of straight-grained trunk like the coniferous woods, the present indications are that it is impracticable to obtain all these relations in the case of cross-grained woods like red gum. The outcome of the work depends on the degree to which the cull material from the heart near the butt of the tree is excluded on account of shakes, rot, etc.

The following table shows the relative percentage of culls in heart-wood and sapwood of the specimens cut from logs procured in Alabama and tested in cross bending, as reported in Table V:

Culls in red gum logs used in cross-bending tests.

	Heartwood.	Sapwood.	Total.
Total number of specimens cut from logs.....	32	16	48
Total number of specimens tested.....	69	17	86
Per cent of waste in culls	53	6	44

The general procedure in taking samples of red gum from various parts of the country is to select a bolt from the trunk at a distance from the ground sufficient to avoid rot and shakes. This bolt will furnish test pieces for the determination of the strength of the heartwood and sapwood. The problem of determining the proportion of merchantable material in a tree is for the inspector, forester, or mill man—not a problem for the testing machine. The test pieces from the bolt will also serve to determine the difference of strength between vigorous young trees and mature trees.

That portion of the results of the tests on the Alabama logs which is of interest in connection with this circular is given in Table V. This table gives a general summary of the strength of red gum heart and sap pieces. The logs were shipped from Alabama to the timber-testing station of the Bureau of Forestry at Lafayette, Ind., and there sawed up into 4 by 4 inch test pieces. The green pieces were tested as soon as possible after sawing. The time elapsing from the sawing of the logs until the end of the tests was about five weeks. The test pieces were kept at the moisture of green timber by a cover of sacking, which was sprinkled day by day. Each test piece was put in a moist closet for two days preceding the actual test. As timber has to dry to a degree of moisture below 33 per cent before any subsequent drying begins to affect the strength of the fiber, and the average moisture of these green specimens was 86.4 per cent, it is evident that the values given are those for green timber. The partially kiln-dried material was the result of an attempt to dry some of these 4 by 4 inch gum sticks in a kiln without subsequent air drying. The kiln drying consisted of the following operations: The sticks were steamed for forty-eight hours with live steam, producing a temperature in the kiln of 110° to 125° F. The steam was then shut off, and the kiln heated for 35 days to a temperature varying from 85° F. on the first few days to 150° and 160° F. at the last. Checking and twisting were most noticeable during the first four or five days in the kiln, after which no large increase was observed. It was noticed upon removal from the kiln that the surfaces of all the timber were apparently dry, having the convex surface peculiar to kiln-dried timber. Upon cutting into the pieces it was found that the heartwood had dried only to a depth of three-quarters of an inch. The sapwood had dried from a depth of 1½ inches to thorough dryness. Subsequent kiln-drying

tests on 2 by 2 inch red gum heartwood stock have shown satisfactory results. In the latter case a much slower and drier heat was given the specimens, which were afterwards steamed and bent into carriage-wood stock.

To determine the effect of close piling on green wood 34 specimens of heartwood and 22 specimens of sapwood were close-piled in a green condition in the laboratory and allowed to remain for six months, developing sap-stain and fungus growth. These specimens were afterwards tested. The results of the tests on this "blued" timber are compared in Table VI with the results of the tests given in Table V. As has been shown in previous tests with pine, both in Germany and in the United States, the effect of this "bluing" is not detrimental to the strength of the timber.

It was desired to ascertain if red gum had the mechanical properties which would fit it for use in the vehicle industry. Factory tests showed that this wood could be steamed and bent, and that it took a good finish. A series of tests was made of hickory in comparison with red gum. Table VII shows the relative bending and compression strength of the four grades of dry commercial hickory. The specimens were all kiln-dried and then seasoned in the laboratory to nearly the same per cent of moisture. The results are all based on specimens nominally $1\frac{1}{2}$ inches square in cross section by 30 inches long, selected by an expert grader in the mill yard, all specimens free from knots, cross grain, and other defects. The strength of the red gum in Table VII represents tests on clear heartwood practically 2 inches square in cross section by 30 inches long, kiln-dried to 13.5 per cent moisture. The actual values obtained in the tests are increased by 42 per cent so as to represent the strength of this red gum at 8 per cent of moisture, in order to form a fair comparison with the hickory.

The difference between red gum and hickory is more marked in impact tests than in tests under gradual loading. Torsion tests bring out very well the difference in the structure of the two woods. The better grades of hickory develop a long fiber, which "brooms out" after rupture, the test piece submitting to a large degree of twisting before rupture. Red gum, on the contrary, opens up longitudinally at a small angle of twist, showing a crooked grain and short fiber. The results of a careful examination of the mechanical properties of the red gum indicate that it is inferior in strength to the poorest grade of hickory. Further discussion will appear in the bulletin on red gum.

APPENDIX.

NOTES ON TABLE I.

The moisture in the beams was determined by the section method. An inch section was sawed from the middle and from one of the quarter points of the span and dried at 100° C. to a constant weight. To determine the amount of moisture driven off by the saw a section one-half inch thick was sawed next to the section 1 inch thick. It appears that the difference between the moisture at the middle and the one-quarter points of the span is negligible, and that the moisture driven off from a 1-inch section by the saw is also negligible. A very careful examination of longleaf pine and red fir shows that the same is true of the correction to the moisture per cent due to the volatile oil driven off from the sections in the oven. The per cent of moisture is computed with reference to the dry weight of the wood.

The annual rings per inch are a measure of the rapidity of growth. A ring consists of the light springwood and the dense summer wood added by the tree in one year. Thus 20 rings per inch means that the tree added 2 inches to its diameter in twenty years.

The dry weight per cubic foot is the number of pounds of wood in 1 cubic foot. The weight of 1,000 feet board measure may be obtained by multiplying the weight per cubic foot by 83½.

The modulus of rupture and the fiber stress at elastic limit are measures of the strength of the wood in cross bending, and the modulus of elasticity is the measure of the stiffness in cross bending. The method of computing these is described in Bulletin No. 8 of the Bureau of Forestry. The elastic limit is the real elastic limit, not the apparent elastic limit defined in Bulletin No. 8. Loads were applied continuously at a speed of one-quarter inch per minute for beams 6 by 8 inches in cross section and at a speed of one-eighth inch per minute for beams 8 by 16 inches in cross section.

RULES FOR INSPECTION AND GRADING.

The rules of inspection and grading referred to in this circular are here reproduced.

From the classification and inspection rules for yellow pine lumber, adopted by the Georgia Sawmill Association at Jacksonville, Fla., 1902.

MERCHANTABLE INSPECTION, 1902.

Dimension sizes.—All square lumber shall show two-thirds heart on two opposite sides; other sizes shall show two-thirds heart on faces, except for lengths exceeding

40 feet, then to show half heart on two opposite sides or faces for the additional length—all free from round shakes that show on the surface or through shakes or unsound knots.

STANDARD INSPECTION, 1902.^a

Dimension.—Shall be square edge, except that sizes 10-inch or over may have 2-inch wane one-third the length on one corner, or one-sixth the length on two corners, or one-ninth the length on three corners, or one-twelfth the length on four corners; wane to be measured on face side. All free from round or through shakes or unsound knots.

From the Pacific Coast standard grading rules for Douglas fir, adopted 1900.

MERCHANTABLE.

This grade shall consist of sound, strong lumber, free from shakes, large, loose, or rotten knots, and defects that materially impair its strength; well manufactured and suitable for good substantial constructional purposes.

Will allow—

Occasional variations in sawing or occasional scant thicknesses, sound knots, pitch seams, and sap on corners, one-third the width and one-half the thickness. Defects in all cases to be considered in connection with the size of the piece and its general quality.

SECONDS.

This grade shall consist of lumber having defects which exclude it from grading as merchantable.

Will allow—

Knots and defects which render it unfit for good substantial constructional purposes, but suitable for an inferior class of work.

SELECTS.

Shall be sound, strong lumber, good grain, well sawn.

Will allow—

In sizes 6 by 6 and less, knots not to exceed 1 inch in diameter; sap on corners one-fourth the width and one-half the thickness; small pitch seams when not exceeding 6 inches in length.

In sizes over 6 by 6, knots not to exceed 2 inches in diameter, varying according to the size of the piece; sap on corner not to exceed 3 inches on both face and edge; pitch seams not to exceed 8 inches in length.

Defects in all cases to be considered in connection with the size of the piece and its general quality.

DESCRIPTION OF BEAMS.

The limits of this circular will not allow a detailed description of the sticks the results of tests of which are given in Table I. The stick whose modulus of rupture corresponds to the average modulus of rupture of the merchantable or square edge grade in Table I is selected for description in each case.

HISTORY OF SHIPMENT "A" RED FIR.

Cut in township 17 south, range 2 east, Willamette Meridian, on McKenzie River, west slope Cascade Mountains, Lane County, Oreg. Shipped from Coburg, Oreg., May 8; received at Berkeley, Cal., May 25, 1903.

^a Called "square edge" in Charleston and in this circular.

INDIVIDUAL DESCRIPTION OF TIMBERS TESTED.

Red fir, shipment "A," 6 by 8 average select.

Rings per inch, 13; color, medium yellow; imperfections: Side *a*, one weather check; side *b*, pitch seam; side *c*, pitch seam, weather checks; side *d*, pitch seam, weather checks.

Red fir, shipment "A," 6 by 8 maximum select.

Rings per inch, 20.5; color, medium yellow; imperfections: Side *a*, three knots 0.5 to 0.7 inches in diameter, small weather checks; side *b*, clear; side *c*, weather checks; side *d*, clear.

Red fir, shipment "A," 6 by 8 minimum select.

Rings per inch, 21; color, medium yellow; imperfections: Side *a*, weather checks; side *b*, pitch seam; side *c*, one-half-inch knot and weather checks; side *d*, pitch seam.

Red fir, shipment "A," 6 by 8 average merchantable.

Rings per inch, 22; color, medium red; imperfections: Side *a*, 2 knots about 1 inch in diameter, weather checks; side *b*, 1 knot 3 by 2½ inches, broken out; side *c*, 6 knots 1 to 1½ inches in diameter, checks; side *d*, 1 small knot.

Red fir, shipment "A," 6 by 8 maximum merchantable.

Rings per inch, 22; color, medium yellow; imperfections: Side *a*, clear; side *b*, clear; side *c*, two ½-inch sound knots; side *d*, clear.

Red fir, shipment "A," 6 by 8 minimum merchantable.

Rings per inch, 25; color, medium yellow; imperfections: Side *a*, one ½-inch sound knot; side *b*, clear; side *c*, 8 knots from ½ to 1 inch in diameter; side *d*, 2 knots.

Red fir, shipment "A," 6 by 8 average seconds.

Rings per inch, 8; color, medium red; imperfections: Side *a*, 16 sound knots ½ to 2 inches in diameter, check; side *b*, 4 knots 1 to 1½ inches in diameter, sound; side *c*, 6 loose knots 1 to 1½ inches in diameter, checked; side *d*, 5 knots from 1 to 1½ inches in diameter, all sound.

Red fir, shipment "A," 6 by 8 maximum seconds.

Rings per inch, 18; color, medium red; imperfections: Side *a*, 3 knots 1 to 2½ inches in diameter, 2 loose; side *b*, 7 knots 1 to 3 inches in diameter, loose; side *c*, 4 loose knots 1 inch in diameter, pitch seam; side *d*, no knots, pitch seam and check.

Red fir, shipment "A," 6 by 8 minimum seconds.

Rings per inch, 5.4; color, medium red; imperfections: Side *a*, 13 knots $\frac{1}{2}$ to $1\frac{1}{2}$ inches in diameter, 2 loose, weather checks; side *b*, 5 knots $\frac{1}{2}$ to $1\frac{1}{2}$ inches in diameter, 2 loose, weather checks; side *c*, 5 knots $\frac{1}{2}$ to $1\frac{1}{2}$ inches in diameter, 1 loose, weather checks; side *d*, 11 knots $\frac{1}{2}$ to 2 inches in diameter, 3 loose, weather checks.

Loblolly pine, 8 by 8 average square edge, green.

History: From Urban Wharf, King and Queen County, Va.; in yard one week. Rings per inch, 2.6; color, light yellow; imperfections: Side *a*, 11 knots from 1 to 3 inches in diameter, all sap; side *b*, 6 knots about 2 inches in diameter, all sap; side *c*, 6 knots from $2\frac{1}{2}$ to $4\frac{1}{2}$ inches in diameter, all sap; side *d*, 9 knots from $1\frac{1}{2}$ to 3 inches in diameter, all sap.

Loblolly pine, 8 by 8 maximum square edge, green.

Rings per inch, 3.2; color, light yellow; imperfections: Side *a*, 8 knots from 1 to $2\frac{1}{2}$ inches in diameter; side *b*, 7 knots from $1\frac{1}{2}$ to 3 inches in diameter; side *c*, 5 knots from $\frac{1}{2}$ to 3 inches in diameter; side *d*, 7 knots from 1 to 4 inches in diameter, sap on all four faces.

Loblolly pine, 8 by 8 minimum square edge, green.

Rings per inch, 3; color, light yellow, turning to yellowish white on exposure; imperfections: Side *a*, 3 knots; side *b*, 6 knots; side *c*, 7 knots; side *d*, 8 knots from 3 to 5 inches in diameter.

Western hemlock, 8 by 16 maximum merchantable.

History: Cut in township 20 south, range 1 east, Willamette Meridian, west slope Cascade Mountains, Lane County, Oreg. Shipped from Saginaw May 12, received at Berkeley, Cal., May 25, 1903. Rings per inch, 11.8; imperfections: Side *a*, 11 knots $\frac{1}{2}$ to 1 inch in diameter, 3 loose, weather checks; side *b*, badly weather checked; side *c*, 10 knots $\frac{1}{2}$ to 1 inch in diameter, 6 loose, weather checked; side *d*, 2 knots $1\frac{1}{2}$ inches in diameter, sound, weather checked.

Western hemlock, 8 by 16 minimum merchantable.

Rings per inch, 11; imperfections: Side *a*, 10 small knots $\frac{1}{2}$ to $1\frac{1}{2}$ inches in diameter, 4 loose, 6 sound; side *b*, 3 knots, 2 loose; side *c*, 8 knots, all sound, checked; side *d*, 2 knots, both loose, weather checked.

Loblolly pine, 8 by 14 average square edge.

History: Felled about September 1, 1903; sawed at mill September 15; tested November 4, 1903. Rings per inch, 7; color, sap, greenish

white; imperfections: Side *a*, all sap; side *b*, three-fourths sap; side *c*, all sap; side *d*, 7 knots 1 to $2\frac{1}{2}$ inches in diameter, two-thirds sap.

Loblolly pine, 8 by 14 maximum square edge.

Rings per inch, 6; color, heart, brown; sap, greenish white; imperfections: Side *a*, all sap; side *b*, 10 knots $\frac{1}{2}$ to $3\frac{1}{2}$ inches in diameter, one-half sap; side *c*, all sap; side *d*, one $\frac{1}{2}$ -inch knot, two-thirds sap.

Loblolly pine, 8 by 14 minimum square edge.

Rings per inch, 5.75; color, sap, greenish white, heart, brown; imperfections: Side *a*, all sap; side *b*, seven-eighths sap, one 2-inch knot; side *c*, all sap; side *d*, nine-tenths sap.

Longleaf pine, 10 by 12 average merchantable.

History: Grown in southern Georgia; in lumber yard since February, 1902; tested September 24, 1902. Rings per inch, 13; imperfections: Side *a*, $1\frac{1}{2}$ by $2\frac{1}{2}$ inch knot in upper half of side; side *b*, 2 small knots in upper half of side, 1.1 by $\frac{1}{2}$ inch and $1\frac{1}{2}$ by $\frac{1}{4}$ inch; side *c*, 4 small knots in center of side, 0.2 by 0.25 inch, 1.4 by 0.2 inch, 1.2 by 2 inch, and 0.7 by 0.5 inch; side *d*, 4 small knots and slight checks near upper end, 1.0 by 0.25 inch, 2.2 by 0.2 inch, 1.1 by 0.25 inch, 1.0 by 0.6 inch.

Longleaf pine, 10 by 12 maximum merchantable.

Rings per inch, 14; imperfections: A few slight checks in each side; 1 knot in side *a*, 3 by 4 inches, and 1 in side *d*, 2.5 by $\frac{1}{2}$ inches.

Longleaf pine, 10 by 12 minimum merchantable.

Rings per inch, 13; imperfections: Side *a*, 3 knots, $\frac{1}{2}$ by $\frac{1}{2}$ inch, $\frac{1}{2}$ by $\frac{1}{2}$ inch, $\frac{1}{4}$ by $\frac{1}{4}$ inch, checks; side *b*, 4 knots, $1\frac{1}{2}$ by $1\frac{1}{2}$ inches, $1\frac{1}{2}$ by $1\frac{1}{2}$ inches, 1 by 1 inch, 1 by 1 inch; side *c*, 6 knots, $\frac{1}{2}$ by $\frac{1}{2}$ inch, $\frac{1}{2}$ by $\frac{1}{2}$ inch, 1 by $1\frac{1}{2}$ inches, 1 by 1 inch, $\frac{1}{2}$ by $\frac{1}{2}$ inch, 1 by 1 inch; side *d*, 1 knot $\frac{1}{2}$ by $\frac{1}{2}$ inch.

TABLE I.—*Cross-bending strength of large sticks.*

Species.	Where grown.	Section.	Span.	Condition.		Select.								Merchantable.								Seconds.								All grades.							
						Number of tests.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Longitudinal shear.	Moisture.	Number of rings per inch.	Dry weight per cubic foot.	Number of tests.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Longitudinal shear.	Moisture.	Number of rings per inch.	Dry weight per cubic foot.	Number of tests.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Longitudinal shear.	Moisture.	Number of rings per inch.	Dry weight per cubic foot.	Number of tests.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Longitudinal shear.	Moisture.	Number of rings per inch.	Dry weight per cubic foot.
							Lbs. per sq. in.	Lbs. per sq. in.	^{1,000} Lbs. per sq. in.	Lbs. per sq. in.	Per cent.		Lbs.		Lbs. per sq. in.	Lbs. per sq. in.	^{1,000} Lbs. per sq. in.	Lbs. per sq. in.	Per cent.		Lbs.		Lbs. per sq. in.	Lbs. per sq. in.	^{1,000} Lbs. per sq. in.	Lbs. per sq. in.	Per cent.		Lbs.		Lbs. per sq. in.	Lbs. per sq. in.	^{1,000} Lbs. per sq. in.	Lbs. per sq. in.	Per cent.		Lbs.
Red fir	A	6" x 8"	16'		Average Maximum Minimum	4	7,270 9,210 6,300	10,162 10,910 8,690	2,226 2,665 1,785	195 209 168	19.6 20.2 18.9	19.3 22.2 13.0	31.90 35.80 27.85	15	6,190 8,160 4,360	8,094 10,875 5,060	1,917 2,430 1,508	254 517 79	20.3 22.8 18.3	20.3 33.3 11.9	30.45 34.25 27.20	10	4,460 5,260 2,710	6,343 7,930 4,380	1,555 2,065 1,230	122.0 151.0 85.0	18.9 19.5 17.5	10.3 18.0 4.6	25.50 28.65 21.55	29	5,740 9,210 2,710	7,775 10,910 4,380	1,835 2,665 1,230	200 517 79	19.7 22.8 17.5	16.7 33.3 4.6	28.95 35.85 21.55
Red fir	A	8" x 16"	16'		Average Maximum Minimum	4	5,970 6,750 5,200	8,275 8,680 7,920	1,987 2,200 1,810	330 345 314	23.4 26.5 20.4	14.2 15.2 13.5	33.9 35.4 32.0	4	4,920 5,270 4,440	6,632 7,190 5,710	1,661 1,880 1,365	265 287 228	20.9 23.8 19.0	12.7 18.8 6.2	27.2 28.9 25.2	8	5,450 6,750 4,440	7,830 8,680 5,710	1,824 2,200 1,365	297 345 228	22.6 26.5 19.0	13.4 18.8 6.2	30.5 35.4 25.2								
Red fir	B	6" x 8"	16'		Average Maximum Minimum	12	4,030 4,860 3,260	6,060 6,883 5,351	1,280 1,503 1,047	140 161 120	27.4 36.5 22.5	16.5 26.0 7.0	23.55 27.9 21.1	11	3,680 5,150 2,380	5,185 7,534 2,730	1,270 1,710 790	117 161 65	27.8 34.3 20.5	9.0 22.0 5.0	24.29 27.0 21.9	13	2,970 4,040 1,165	3,996 5,790 1,985	1,491 1,554 762	91.3 123.0 56.0	28.1 34.7 21.9	11.0 24.0 6.0	25.15 38.7 20.6	36	3,580 5,150 1,165	5,075 7,534 1,985	1,234 1,710 762	115 161 56	27.7 36.5 20.5	12.4 26.0 5.0	24.19 38.7 20.6
Red fir	B	8" x 16"	16'		Average Maximum Minimum	2	4,830 5,010 4,660	6,731 7,385 6,077	1,250 1,273 1,227	292 318 266	28.4 30.5 26.4	6.5 7.0 6.0	28.1 30.2 26.0	4	4,070 4,720 2,880	5,778 6,790 4,360	1,460 1,520 1,370	228 261 173	22.9 23.5 21.6	6.0 8.0 5.0	33.1 36.9 31.9	12	3,620 4,880 2,550	4,600 7,000 2,940	1,295 1,620 872	193.0 281.0 117.0	24.2 28.7 20.8	6.6 12.0 3.0	30.7 34.3 27.0	18	3,860 5,010 2,550	5,098 7,385 2,940	1,327 1,620 872	212 318 117	24.4 30.5 20.8	6.4 12.0 3.0	31.0 36.9 26.0
Red fir	C	6" x 8"	16'		Average Maximum Minimum	10	6,280 7,210 4,720	9,247 11,000 7,440	1,923 2,180 1,510	185 215 148	22.1 23.8 18.8	21.1 25.9 11.1	29.4 30.3 26.3	8	5,360 6,160 4,700	7,887 9,300 6,340	1,836 2,100 1,590	156 182 127	20.6 21.8 17.6	16.0 27.0 9.4	29.4 30.9 27.6	6	4,350 5,860 1,980	6,177 8,420 3,770	1,747 1,945 1,680	122.0 166.0 74.0	20.6 21.9 18.2	15.0 23.2 8.0	28.6 30.0 26.2	24	5,560 7,210 1,980	8,030 11,000 3,770	1,850 2,180 1,510	160 215 74	21.2 23.8 17.5	17.9 25.9 8.0	29.1 30.9 26.2
Red fir	C	8" x 16"	16'		Average Maximum Minimum	4	4,800 5,220 4,460	6,990 7,260 6,430	1,570 1,690 1,450	365 395 310	26.1 29.2 23.0	25.4 29.4 22.7	27.2 27.2 27.2	2	4,560 4,670 4,460	6,570 6,620 6,520	1,410 1,455 1,365	285 287 283	24.6 25.6 23.6	29.0 29.4 28.6	25.5 25.6 25.4	6	4,720 5,220 4,460	6,850 7,260 6,430	1,517 1,690 1,365	333 395 283	25.3 29.2 23.0	26.8 29.4 22.7	26.1 27.2 25.4								
Western hemlock	Oregon	6" x 8"	7'		Average Maximum Minimum	4	4,550 5,060 3,880	6,488 7,190 5,920	1,337 1,505 1,110	292 313 270	33.9 40.3 28.1	14.2 19.2 10.0	27.4 28.0 26.0	16	3,910 5,310 2,650	6,488 7,090 4,250	1,337 1,597 1,010	292 343.0 188.0	33.9 42.4 23.6	14.2 28.4 23.6	27.4 28.4 24.7	16	3,910 5,310 2,650	5,555 7,090 4,250	1,213 1,597 1,010	266.0 343.0 188.0	30.1 42.4 23.6	9.1 14.0 5.9	26.8 28.4 23.6	20	4,030 5,310 2,650	5,742 7,190 4,250	1,238 1,597 1,010	271 343 188	31.0 42.4 23.6	10.2 19.2 5.9	26.9 28.4 23.6
Western hemlock	Oregon	8" x 16"	16'		Average Maximum Minimum	2	3,440 4,450 2,430	4,775 5,130 4,420	1,442 1,575 1,310	161 209 113	35.2 42.4 28.1	13.3 14.7 11.9	28.4 29.0 27.8	8	3,980 4,420 3,330	5,200 6,060 3,900	1,275 1,540 1,163	211.0 246.0 159.0	34.5 51.2 23.6	9.3 11.4 6.1	26.1 28.4 24.7	10	3,870 4,450 2,430	5,115 6,060 3,900	1,308 1,575 1,163	201 246 113	34.6 51.2 23.6	10.1 14.7 6.1	26.6 29.0 24.7								
Loblolly pine	Virginia	8" x 8"	6' to 15'	Green	Average Maximum Minimum	15	1,847 3,185 878	3,281 4,720 1,545	729 1,150 356	104.0 246.0 33.0	72.6 104.6 61.9	3.1 3.5 2.5	26.3 31.9 20.0	15	1,847 3,185 878	3,281 4,720 1,545	729 1,150 356	104.0 246.0 33.0	72.6 104.6 61.9	3.1 3.5 2.5	26.3 31.9 20.0	15	1,847 3,185 878	3,281 4,720 1,545	729 1,150 356	104.0 246.0 33.0	72.6 104.6 61.9	3.1 3.5 2.5	26.3 31.9 20.0	15	1,847 3,185 878	3,281 4,720 1,545	729 1,150 356	104.0 246.0 33.0	72.6 104.6 61.9	3.1 3.5 2.5	26.3 31.9 20.0
Loblolly pine	Virginia	8" x 8"	6' to 15'	Air dried	Average Maximum Minimum	13	3,089 5,300 674	4,874 8,950 1,470	1,164 1,728 606	140.0 348.0 45.0	23.3 34.7 17.8	5.1 8.8 2.7	28.8 36.2 23.1	13	3,089 5,300 674	4,874 8,950 1,470	1,164 1,728 606	140.0 348.0 45.0	23.3 34.7 17.8	5.1 8.8 2.7	28.8 36.2 23.1	13	3,089 5,300 674	4,874 8,950 1,470	1,164 1,728 606	140.0 348.0 45.0	23.3 34.7 17.8	5.1 8.8 2.7	28.8 36.2 23.1	13	3,089 5,300 674	4,874 8,950 1,470	1,164 1,728 606	140.0 348.0 45.0	23.3 34.7 17.8	5.1 8.8 2.7	28.8 36.2 23.1
Loblolly pine	Virginia	4" x 8"	10'	Air dried then soaked.	Average Maximum Minimum	12	2,078 3,760 1,020	5,100 6,240 3,520	1,192 1,640 842	156.0 190.0 117.0	46.3 77.7 33.4	6.4 19.0 4.0	29.1 32.5 22.5	12	2,078 3,760 1,020	5,100 6,240 3,520	1,192 1,640 842	156.0 190.0 117.0	46.3 77.7 33.4	6.4 19.0 4.0	29.1 32.5 22.5	12	2,078 3,760 1,020	5,100 6,240 3,520	1,192 1,640 842	156.0 190.0 117.0	46.3 77.7 33.4	6.4 19.0 4.0	29.1 32.5 22.5	12	2,078 3,760 1,020	5,100 6,240 3,520	1,192 1,640 842	156.0 190.0 117.0	46.3 77.7 33.4	6.4 19.0 4.0	29.1 32.5 22.5
Loblolly pine	Virginia	4" x 8"	10'	Air dried one year.	Average Maximum Minimum	8	3,284 4,900 2,400	6,319 8,370 3,640	1,219 1,695 894	196.0 275.0 120.0	19.4 21.6 14.5	7.9 10.3 6.0	29.4 33.1 23.8	8	3,284 4,900 2,400	6,319 8,370 3,640	1,219 1,695 894	196.0 275.0 120.0	19.4 21.6 14.5	7.9 10.3 6.0	29.4 33.1 23.8	8	3,284 4,900 2,400	6,319 8,370 3,640	1,219 1,695 894	196.0 275.0 120.0	19.4 21.6 14.5	7.9 10.3 6.0	29.4 33.1 23.8	8	3,284 4,900 2,400	6,319 8,370 3,640	1,219 1,695 894	196.0 275.0 120.0	19.4 21.6 14.5	7.9 10.3 6.0	29.4 33.1 23.8
Loblolly pine	South Carolina	8" x 14"	16'	Air dried	Average Maximum Minimum	20	3,610 5,210 2,460	6,187 8,680 4,450	1,479 1,920 932	258.0 322.0 146.0	37.2 59.2 26.1	6.0 8.0 4.0	31.2 36.9 25.0	20	3,610 5,210 2,460	6,187 8,680 4,450	1,479 1,920 932	258.0 322.0 146.0	37.2 59.2 26.1	6.0 8.0 4.0	31.2 36.9 25.0	20	3,610 5,210 2,460	6,187 8,680 4,450	1,479 1,920 932	258.0 322.0 146.0	37.2 59.2 26.1	6.0 8.0 4.0	31.2 36.9 25.0	20	3,610 5,210 2,460	6,187 8,680 4,450	1,479 1,920 932	258.0 322.0 146.0	37.2 59.2 26.1	6.0 8.0 4.0	31.2 36.9 25.0
Longleaf pine	Georgia	10" x 12"	16'		Average Maximum Minimum	22	5,581 9,601 3,547	8,384 11,410 4,836	1,820 2,920 1,167	252 330 151	27.3 34.5 20.0	18.0 29.0 11.0	42.9 49.4 31.4	22	5,581 9,601 3,547	8,384 11,410 4,836	1,820 2,920 1,167	252 330 151	27.3 34.5 20.0	18.0 29.0 11.0	42.9 49.4 31.4	22	5,581 9,601 3,547	8,384 11,410 4,836	1,820 2,920 1,167	252 330 151	27.3 34.5 20.0	18.0 29.0 11.0	42.9 49.4 31.4	22	5,581 9,601 3,547	8,384 11,410 4,836	1,820 2,920 1,167	252 330 151	27.3 34.5 20.0	18.0 29.0 11.0	42.9 49.4 31.4
Longleaf pine	South Carolina	6" x 10" to 10" x 16"	16'		Average Maximum Minimum	4	3,697 4,620 3,080	7,212 8,640 6,070	1,611 1,875 1,230	296 366 238	23.3 26.1 18.1	13.5 18.0 10.0	37.6 47.5 33.1	4	3,697 4,620 3,080	7,212 8,640 6,070	1,611 1,875 1,230	296 366 238	23.3 26.1 18.1	13.5 18.0 10.0	37.6 47.5 33.1	4	3,697 4,620 3,080	7,212 8,640 6,070	1,611 1,875 1,230	296 366 238	23.3 26.1 18.1	13.5 18.0 10.0	37.6 47.5 33.1	4	3,697 4,620 3,080	7,212 8,640 6,070	1,611 1,875 1,230	296 366 238	23.3 26.1 18.1	13.5 18.0 10.0	37.6 47.5 33.1

NOTE.—The figures along horizontal lines do not refer to any one stick. Thus, the minimum modulus of rupture and minimum percentage of moisture were not found in the same stick. Figures written as subscripts to the figures for longitudinal shear indicate the number of sticks falling in that manner.

TABLE IIa.—*Compressive strength parallel to the fiber.*

Species.	Where grown.	Dimensions.	Grade.	Number of tests.	Stress at elastic limit.	Stress at rupture.	Moisture.	Number of rings per inch.	Weight.
Red fir.....	A.....	5" x 5"	All:		<i>Lbs. per sq. inch.</i>	<i>Lbs. per sq. inch.</i>	<i>Per cent.</i>		<i>Lbs. per cubic ft.</i>
			Average	80	{ 3,590	{ 4,788	{ 20.7	15.5	29.0
			Maximum		{ 5,280	{ 7,070	{ 22.7		
			Minimum		{ 1,970	{ 2,780	{ 17.5		
Red fir.....	B.....	5" x 5"	All:						
			Average	74	{ 2,590	{ 3,376	{ 26.3	.....	26.0
			Maximum		{ 3,760	{ 4,515	{ 36.5		
			Minimum		{ 1,270	{ 1,620	{ 20.0		
Red fir.....	C.....	5" x 5"	All:						
			Average	63	{ 3,840	{ 4,886	{ 20.8	19.4	28.4
			Maximum		{ 5,220	{ 6,100	{ 28.3		
			Minimum		{ 2,500	{ 3,440	{ 15.7		
Western hemlock	Oreg..	5" x 5"	All:						
			Average	57	{ 2,560	{ 3,353	{ 32.0	9.3	25.7
			Maximum		{ 3,930	{ 4,620	{ 47.1		
			Minimum		{ 1,520	{ 2,660	{ 22.2		
Loblolly pine....	Va.....	8" x 8"	Square edge:						
			Average	13	{ 1,346	{ 1,988	{ 74.0	.....	26.4
			Maximum		{ 1,950	{ 2,485	{ 104.6		
			Minimum		{ 819	{ 1,362	{ 61.9		
Loblolly pine....	S. C....	8" x 8"	Square edge:						
			Average	24	{ 2,748	{ 3,862	{ 39.0	.....	29.6
			Maximum		{ 4,490	{ 5,600	{ 84.0		
			Minimum		{ 1,925	{ 3,035	{ 22.6		
Longleaf pine ...	Ga.....	4" x 6"	Merchantable:						
			Average	44	{ 3,650	{ 4,862	{ 26.9	.....	35.7
			Maximum		{ 5,200	{ 5,950	{ 34.8		
			Minimum		{ 2,391	{ 3,290	{ 21.7		

TABLE IIb.—*Compressive strength at right angles to the fiber.*

Species.	Where grown.	Dimensions.	Grade.	Number of tests.	Fiber stress at elastic limit.	Moisture.	Dry weight.
Red fir.....	A, B, C	4" x 4" x 16" ..	All:		<i>Lbs. per sq. inch.</i>	<i>Per cent.</i>	<i>Lbs. per cubic ft.</i>
			Average	142	{ 597	{ 19.5	28.8
			Maximum		{ 1,300	{ 22.4	
			Minimum		{ 402	{ 17.5	
Western hemlock.	Oregon	4" x 4" x 16" ..	All:				
			Average	57	{ 478	{ 34.1	26.7
			Maximum		{ 988	{ 53.3	
			Minimum		{ 234	{ 21.0	
Loblolly pine....	Virginia	8" x 8" x 28" ..	Square edge:				
			Average	13	{ 412	{ 74.7	26.1
			Maximum		{ 866	{ 104.6	
			Minimum		{ 195	{ 61.9	
Loblolly pine....	South Carolina ..	8" x 14" x 28" ..	Square edge:				
			Average	23	{ 623	{ 44.8	29.7
			Maximum		{ 937	{ 117.0	
			Minimum		{ 375	{ 23.5	
Longleaf pine ...	Georgia	4" x 4" x 16" ..	Merchantable:				
			Average	22	{ 616	{ 25.1	36.0
			Maximum		{ 875	{ 30.9	
			Minimum		{ 375	{ 21.7	

^a Results of 51 tests.

TABLE IIc.—*Shearing strength.*

Species.	Where grown.	Dimensions.	Grade.	Number of tests.	Number of rings per inch.	Moisture.	Shearing stress (ultimate).
Red fir	A	1.5" x 3"	All:	104	{	<i>Per cent.</i>	<i>Lbs. per sq. inch.</i>
			Average			17.9	702
			Maximum			34.0	1,136
Red fir	B	1.5" x 3"	All:	108	{	5.0	296
			Maximum			22.1	1,025
			Minimum			17.1	286
Western hemlock..	Oregon	1.5" x 3"	All:	120	{	11.1	720
			Average			27.0	1,025
			Maximum			30.0	286
Loblolly pine.....	Virginia	1.5" x 3"	Square edge:	77	{	9.9	764
			Average			23.0	1,058
			Maximum			5.0	496
Loblolly pine.....	South Carolina.	1.5" x 3"	Square edge:	26	{	3.6	657
			Average			11.0	1,047
			Maximum			2.0	342
			Minimum	27	{	36.0	276
			Kiln dried—			5.1	480
			Average			8.5	779
			Maximum	38	{	2.0	251
			Minimum			4.6	607
			Soaked—			1.0	941
			Average	38	{	2.0	276
			Maximum			180.3	941
			Minimum			40.3	276
Longleaf pine	Georgia.....	1.5" x 3"	Merchantable:	38	{	21.6	992
			Average			39.0	1,257
			Maximum			8.0	800
			Minimum			18.5	

TABLE IIId.—*Resistance to splitting due to longitudinal shear under cross bending.*

Species.	Where grown.	Dimensions.	Sticks failing.				Sticks not failing.			
			Num-ber.	Shear.			Num-ber.	Shear.		
				Aver-age.	Maxi-mum.	Mini-mum.		Aver-age.	Maxi-mum.	Mini-mum.
				<i>Lbs. per sq. inch.</i>	<i>Lbs. per sq. inch.</i>	<i>Lbs. per sq. inch.</i>		<i>Lbs. per sq. inch.</i>	<i>Lbs. per sq. inch.</i>	<i>Lbs. per sq. inch.</i>
Red fir.....	A.....	{ 8" x 16" x 16' 6" x 8" x 16'	8	297	345	228	24	170	413	79
Red fir.....	B.....	{ 8" x 16" x 16' 6" x 8" x 16'	5	343	517	146	11	201	318	117
Red fir.....	C.....	{ 8" x 16" x 16' 6" x 8" x 16'	7	223	273	173	22	171	390	96
Longleaf pine..	Ga....	10" x 12" x 16'	3	247	395	74	19	243	330	151

TABLE III.—Comparative strength of large and small sticks.

Species.	Where grown.	Cross bending.														Compression parallel to the fiber.											
		Section.	Span.	Number of tests.	Number of rings per inch.	Moisture.	Average.			Maximum.			Minimum.			Dimensions.	Number of tests.	Number of rings per inch.	Moisture.	Crushing strength.							
							Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.					Average.		Maximum.		Minimum.			
																				At elastic limit.	At rupture.	At elastic limit.	At rupture.	At elastic limit.	At rupture.		
						Per cent.	Lbs. per sq. inch.	Lbs. per sq. inch.	1,000 lbs. per sq. inch.	Lbs. per sq. inch.	Lbs. per sq. inch.	1,000 lbs. per sq. inch.	Lbs. per sq. inch.	Lbs. per sq. inch.	1,000 lbs. per sq. inch.				Per cent.	Lbs. per sq. inch.	Lbs. per sq. inch.	Lbs. per sq. inch.	Lbs. per sq. inch.	Lbs. per sq. inch.	Lbs. per sq. inch.		
Red fir.....	A.....	6'' x 8'' 2'' x 2''	16' 24''	29 52	16.7 17.9	19.7 18.7	5,740 6,840	7,775 10,220	1,835 1,644	8,290 9,420	10,910 13,340	2,665 2,175	4,300 6,790	4,380 6,790	1,230 995	5' x 5' x 30'' .. 2' x 2' x 10'' ..	51 104	16.4 18.9	19.6 18.3	3,550 3,300	4,815 4,906	5,270 4,770	7,070 6,060	1,970 2,140	3,330 3,235		
Ratio of small sticks to large..						.95	1.17	1.315	.898	1.13	1.12	.815	1.59	1.55	.808				.935	.935	1.02	.905	.858	1.085	.971		
Red fir.....	A.....	8'' x 16'' 6'' x 8'' 2'' x 2''	16' 7' 24''	8 16 24	13.4 11.8 14.5	22.6 22.7 22.1	5,450 5,840 6,810	7,830 9,060 10,320	1,824 1,572 1,658	6,750 7,950 8,910	8,680 11,360 12,380	2,200 1,960 2,120	4,440 4,100 4,050	5,710 5,700 6,300	1,365 970 1,270	5' x 5' x 30'' .. 2' x 2' x 10'' ..	29 46	11.8 14.6	22.7 21.0	3,650 3,720	4,740 5,140	4,850 5,170	6,000 6,400	2,140 2,220	2,780 3,500		
Ratio of small sticks to large..						.978	1.25	1.315	.91	1.32	1.43	.965	.915	1.10	.93				1.02	1.09	1.07	1.06	1.05	1.26			
Red fir.....	C.....	8'' x 16'' 5'' x 8'' 2'' x 2''	16' 7' 24''	6 8 14	26.8 24.4 22.4	25.3 25.2 25.3	4,720 4,930 5,724	6,850 7,899 9,110	1,517 1,331 1,432	5,220 5,620 6,480	7,260 8,500 9,460	1,690 1,450 1,680	4,460 4,260 4,860	6,430 6,770 8,520	1,365 1,250 1,260	5' x 8' x 30'' .. 2' x 2' x 10'' ..	15 23	24.4 24.2	25.2 23.6	3,120 2,360	4,235 4,540	3,690 3,150	4,950 5,175	2,520 2,480	3,440 3,880		
Ratio of small sticks to large..						1.00	1.21	1.33	.95	1.24	1.31	.995	1.09	1.32	.925				.95	1.07	.874	1.05	1.00	1.13			
Red fir.....	C.....	5'' x 8'' 2'' x 2''	16' 24''	24 47	17.9 20.9	21.2 18.9	5,360 6,320	8,030 9,780	1,850 1,600	7,220 8,300	11,000 11,750	2,100 1,950	1,980 2,500	3,770 6,380	1,510 1,295	5' x 8' x 30'' .. 2' x 2' x 10'' ..	48 90	17.9 20.8	19.4 18.0	4,170 4,050	5,090 5,293	5,220 4,970	6,100 6,220	2,860 2,760	3,885 3,410		
Ratio of small sticks to large..						.891	1.14	1.22	.865	1.15	1.07	.93	1.26	1.67	.86				.985	1.04	.955	1.02	.963	.888			
Western hemlock	Oregon	8'' x 16'' 6'' x 8'' 2'' x 2''	16' 7' 24''	10 20 40	10.1 10.2 11.0	34.6 31.0 31.6	3,870 4,030 4,950	5,115 5,742 7,871	1,308 1,238 1,314	4,440 5,310 6,980	6,060 7,190 12,300	1,575 1,597 2,160	2,430 2,640 2,390	3,900 4,250 4,470	1,163 1,010 794	5' x 5' x 30'' .. 2' x 2' x 10'' ..	57 77	9.3 11.4	32.0 29.9	2,556 2,860	3,353 3,841	3,940 3,740	4,620 4,770	1,520 1,550	2,660 2,110		
Ratio of small sticks to large..						.915	1.28	1.54	1.005	1.57	2.03	1.37	.988	1.145	.682				.985	1.15	1.14	.955	1.305	1.06	.793		
Loblolly pine.....	Virginia.....	4'' x 8'' 2'' x 2'	10' 30''	12 13	6.4	46.3 44.8	2,078 3,038	5,101 6,719	1,192 1,054	3,760 5,060	6,240 8,470	1,640 1,530	1,020 1,458	3,520 5,420	842 575	4' x 8' x 16'' .. 2' x 2' x 6'' ..	12 12	6.4	46.3 46.3	1,766 3,216	2,785 4,450	2,220 4,450	3,540 4,450	1,275 2,320	2,240 2,320		
Ratio of small sticks to large..						.97	1.46	1.34	.885	1.34	1.32	.935	1.42	1.54	.683				1.00		1.15		1.26		1.03		
Loblolly pine.....	Virginia.....	8'' x 8'' 2'' x 2''	8' to 15' 30''	15 7	3.1 3.5	72.6 74.3	1,847 1,868	3,281 3,916	729 550	3,185 2,810	4,720 5,710	1,150 1,110	878 844	1,545 2,660	356 243	8' x 8' x 20'' ..	12	3.1	74.0	1,346	1,988	1,950	2,485	819	1,362		
Ratio of small sticks to large..						1.02	1.01	1.19	.755	.883	1.21	.97	.962	1.72	.683												
Loblolly pine.....	South Carolina	8'' x 14'' 8'' x 14'' 4'' x 8'' 4'' x 8'' 2'' x 2''	15'-6'' 15'-6'' 6'-6'' 6'-6'' 30''	10 10 12 12 22	6.0 6.0 5.7 5.1 8.5	30.0 44.5 25.9 52.2 68.9	3,953 3,268 3,869 3,443 4,050	6,336 6,039 8,099 7,090 7,890	1,534 1,420 1,542 1,329 1,456	5,210 4,210 4,950 4,570 5,625	8,680 7,080 9,680 8,680 10,600	1,920 1,850 1,865 1,645 2,260	2,460 2,500 2,890 2,660 2,250	3,870 3,950 6,740 6,120 3,990	1,302 932 1,320 1,055 728	4' x 8' x 16'' .. 4' x 8' x 16'' .. 2' x 2' x 6'' ..	12 12 15	5.7 5.1 8.5	25.9 52.2 72.8	3,123 2,373 3,635	4,396 3,528 3,635	4,490 2,880	5,600 4,325 5,085	1,955 1,925	3,810 3,035 2,442		
Ratio of small sticks to large..						1.85	1.12	1.275	.985	1.195	1.35	1.20	.91	1.02	.65					.917		1.02		.715			
Longleaf pine	Georgia.....	10'' x 12'' 4'' x 5'	16' 7'	20 79	18.0	28.2 25.1	5,530 6,200	8,280 9,290	1,807 1,801	7,890 9,953	10,080 14,000	2,408 3,139	3,660 4,250	6,010 5,490	1,356 1,111												
Ratio of small sticks to large..						.89	1.12	1.12	.99	1.26	1.40	1.30	1.16	.915	.820												
Ratio of small sticks to large based on the total number of tests.				122 219		1 1.05	1 1.19	1 1.29	1 .918	1 1.23	1 1.36	1 1.05	1 1.14	1 1.33	1 .782		235 367			1 1.01	1 1.06	1 .952	1 1.08	1 1.03	1 .969		

TABLE IV.—Comparative cross-bending strength of large sticks from the center of green-heart red gum and of the general run of 4'' x 4'' sticks.

Where grown.	Dimensions.		Number of tests.	Moisture.	Specific gravity (dry).	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.
				<i>Per cent.</i>		<i>Lbs. per sq. inch.</i>	<i>Lbs. per sq. inch.</i>	<i>Lbs. per sq. inch.</i>
Missouri.....	4'' x 4'' x 5'	Average.....	184	64.0	.....	3,875	6,200	1,233,000
		Maximum.....		126.0	.....	5,770	7,860	1,890,000
		Minimum.....		50.0	.....	2,010	4,130	730,000
Missouri and Alabama.	4'' x 8'' x 16'..	Average.....	16	76.5	<i>a</i> .460	2,608	4,570	1,075,000
	6'' x 6'' x 16'..	Maximum.....		95.4	.498	3,819	5,550	1,331,000
	6'' x 8'' x 16'..	Minimum.....		52.7	.440	2,100	3,230	600,000
Alabama.....	2'' x 10'' x 16'	Average.....	4	44.8	.....	.....	3,965	.....
		Maximum.....		58.4	.....	.....	4,060	.....
		Minimum.....		31.2	.....	.....	3,875	.....

a Determined on 5 sticks.

TABLE V.—Strength of red gum 4" x 4" in cross section, the green pieces tested immediately after being sawn from the logs.
SPECIMENS FROM 5 MATURE AND 5 IMMATURE TREES (LOG RUN, EXCLUDING CULLS) CUT IN ALABAMA.

Class.	Condition.	Cross bending.						Compression parallel to the fiber.				
		Number of tests.	Moisture.	Specific gravity (dry).	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Number of tests.	Moisture.	Specific gravity (dry).	Crushing strength.	
											At elastic limit.	Maximum load.
Heart.....	Green:	26	<i>Per cent.</i>		<i>Lbs. per sq. inch.</i>	<i>Lbs. per sq. inch.</i>	<i>Lbs. per sq. inch.</i>	21	<i>Per cent.</i>		<i>Lbs. per sq. inch.</i>	<i>Lbs. per sq. inch.</i>
	Average		86.4	0.486	4,049	6,176	1,110,000		86.4	0.486	2,316	2,718
	Maximum		120.7	.562	4,742	8,515	1,591,000		120.7	.562	2,911	3,446
	Minimum		52.8	.422	2,508	4,693	880,000		52.8	.422	1,573	2,058
	Partially kiln dried:	6						4				
	Average		60.7	.495	4,186	6,107	1,123,000		60.7	.495	3,042	3,425
	Maximum		76.0	.548	5,297	6,723	1,248,000		76.0	.548	3,910	4,150
Sap.....	Minimum		49.0	.428	3,204	4,953	1,019,000		49.0	.428	2,400	2,780
	Green:	16						15				
	Average		54.5	.480	4,250	6,341	1,139,000		54.5	.480	2,322	2,933
	Maximum		93.4	.497	5,472	8,212	1,361,000		93.4	.497	2,958	3,625
	Minimum		38.0	.362	2,994	5,177	790,000		38.0	.362	1,631	2,367
	Partially kiln dried:	10						7				
	Average		18.0	.463	7,058	8,524	1,372,000		18.0	.463	4,835	5,793
Heart and sap.....	Maximum		21.3	.482	9,880	12,150	1,572,000		21.3	.482	6,660	7,120
	Minimum		11.1	.426	4,333	4,546	965,000		11.1	.426	3,910	4,150
	Green:	42						36				
	Average		74.0	.473	4,120	6,210	1,122,000		74.0	.473	2,320	2,810
	Maximum		120.7	.562	5,472	8,515	1,591,000		120.7	.562	2,958	3,625
	Minimum		38.0	.362	2,508	4,693	793,000		38.0	.362	1,573	2,058
	Partially kiln dried:	16						11				
	Average		34.0	.475	3,970	7,120	1,280,000		34.0	.475	4,174	4,932
	Maximum		76.0	.548	9,880	12,150	1,572,000		76.0	.548	6,660	7,120
	Minimum		11.1	.426	3,204	4,546	965,000		11.1	.426	2,400	2,780

SPECIMENS FROM 10 MATURE AND 10 IMMATURE TREES (LOG RUN, EXCLUDING CULLS) CUT IN MISSOURI.

Heart.....	Green:	102	64.0	}	}	3,825	6,140	1,223,000	128	64.0	}	}	2,698
	Average					5,460	7,690	1,590,000					3,570
	Maximum					2,130	4,600	912,000					1,580
Sap.....	Green:	11	50.0	}	}	4,380	6,640	1,314,000	8	50.0	}	}	3,054
	Average					5,770	7,710	1,890,000					3,570
	Maximum					2,660	4,240	730,000					2,250

TABLE VI.—*Effect of close piling on red gum.*

[Five mature and 5 immature trees from Hollywood, Ala. Test pieces 4" x 4" x 5'. Timber in piles for six months after being dressed for testing. Sapwood "blued" on surface.]

Species.	Where grown.	Dimensions.	Class.	Treatment.	Cross bending.				
					Number of tests.	Moisture.	Specific gravity (dry).	Modulus of rupture.	Modulus of elasticity.
Red gum	Ala ...	4" x 4" x 5'		Piled:	34	<i>Per cent.</i>	0.502	<i>Lbs. per sq. inch.</i> 6,226	<i>Lbs. per sq. inch.</i> 1,234,000
						Average			
						Maximum ..			
						Minimum ..			
						Average			
						Maximum ..			
				Original:	34	32.6	.480	5,080	1,020,000
						Average	.486	6,176	1,110,000
						Maximum ..	120.7	.562	8,515
						Minimum ..	52.8	.422	4,693
						Average	-----	-----	-----
						Maximum ..	-----	-----	-----
				Sap...	22	Minimum ..	-----	4,660	935,000
						Original:	.450	6,341	1,139,000
						Average			
						Maximum ..			
						Minimum ..			
						Average			
						Maximum ..			
						Minimum ..			
						Average			
						Maximum ..			
						Minimum ..			

TABLE VII.—Comparative strength of red gum and four commercial grades of dry hickory.

Species.	Where grown.	Dimensions.	Grade.	Cross bending.							Compression parallel to the fiber.			
				Number of tests.	Moisture.	Specific gravity (dry).	Fiber stress at elastic limit.	Modulus of rupture.	Modulus of elasticity.	Number of rings per inch.	Number of tests.	Moisture.	Specific gravity (dry).	Crushing strength, maximum load.
Hickory		1.5" x 1.5" x 2.5'	Second growth:	10	<i>Per cent.</i>	0.852	<i>Lbs. per sq. inch.</i>	<i>Lbs. per sq. inch.</i>	<i>Lbs. per sq. inch.</i>	11.0	10	<i>Per ct.</i>	0.852	<i>Lbs. per sq. inch.</i>
			Average.....		5.57		18,998	27,896	2,756,000			5.57		10,596
			Maximum....		9.67		23,680	35,200	3,514,000			9.67		12,900
			Minimum....		3.51		15,720	22,830	2,183,000			3.51		8,233
Hickory		1.5" x 1.5" x 2.5'	Black hickory:	8		.771	18,716	25,693	2,701,000	12.0	8		.771	11,747
			Average.....		8.06		18,716	25,693	2,701,000			8.06		11,747
			Maximum....		8.58		20,160	29,980	3,018,000			8.58		13,350
			Minimum....		7.58		16,100	17,480	2,448,000			7.58		10,480
Hickory		1.5" x 1.5" x 2.5'	XXX:	8		.752	15,730	22,469	2,421,000	21.0	8		.752	10,814
			Average.....		8.43		15,730	22,469	2,421,000			8.43		10,814
			Maximum....		9.42		20,000	27,950	3,218,000			9.42		11,450
			Minimum....		7.82		13,180	18,190	1,895,000			7.82		9,350
Hickory		1.5" x 1.5" x 2.5'	XX:	8		.679	15,540	20,693	2,214,000	32.5	8		.679	10,176
			Average.....		8.74		15,540	20,693	2,214,000			8.74		10,176
			Maximum....		11.50		20,800	25,200	2,498,000			11.50		11,300
			Minimum....		7.75		11,830	16,250	1,750,000			7.75		9,380
Red gum		2" x 2" x 2.5'	Average.....	60	8.0	.462	10,080	15,265	2,016,000	.....	60	8.0	.462	7,298
			Maximum....		.....		11,720	17,700	2,840,000			.....		7,848
			Minimum....		.....		5,540	10,550	1,050,000			.....		4,788